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A Strategic Assessment of Crown Fire Hazard in Montana: Potential Effectiveness and Costs of Hazard Reduction Treatments

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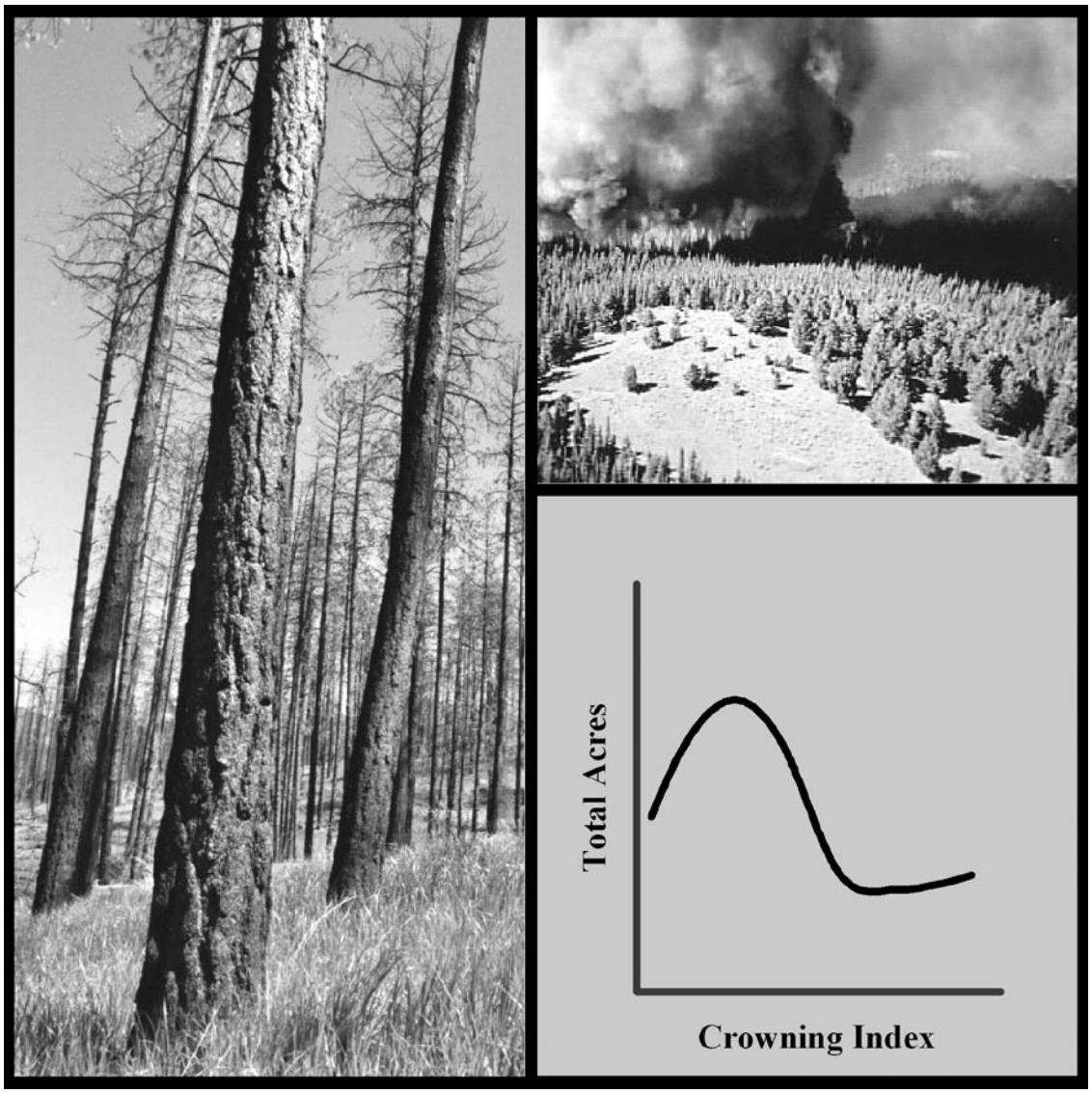

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Abstract

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Estimates of crown fire hazard are presented for existing forest conditions in Montana by density class, structural class, forest type, and landownership. Three hazard reduction treatments were evaluated for their effectiveness in treating historically fire-adapted forests (ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.), Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), dry mixed conifer) that rate high/moderate for fire hazard. Comprehensive restoration treatments that address density, structure, and species composition of high-hazard forests are significantly more effective at reducing hazard than thin-from-below approaches that remove smaller trees only. Trees removed as a byproduct of the restoration treatment yielded net revenues averaging over $600 per acre, whereas the thin-from-below approach would require an out-of-pocket expenditure of over $600 per acre. Post-treatment conditions were projected forward 30 years and reevaluated for hazard. Projections revealed that effectiveness of all treatments diminished over time; however, forests receiving the comprehensive restoration treatment remained substantially lower hazard 30 years after treatment than they would have had they received the alternative treatments.

Keywords: Montana, wildfire, forest inventory, forest restoration, Forest Inventory and Analysis, hazard reduction, treatments, costs.

Summary

Severe and extensive wildfires in the summers of 2000 and 2003 illustrate the hazardous conditions extant over large areas of the Montana landscape. These wildfires have heightened public interest in management actions to address fire hazard. However, developing plans to address hazard at a strategic level requires a fundamental understanding of the problems at hand and the potential effectiveness and costs of treatments to address them.

Consequently, we designed this study to:

- Profile forest conditions in Montana.
- Assess fire hazard.
- Evaluate effectiveness of hazard reduction treatments.
- Estimate treatment costs.

We used Forest Inventory and Analysis data for the state of Montana to profile forest conditions statewide and then assess fire hazard. We evaluated fire hazard by using the Fire and Fuels Extension (FFE) to the Forest Vegetation Simulator (FVS). Hazard was quantified in terms of crowning index, which is the windspeed necessary to sustain a crown fire once a fire has reached the main canopy. Crowning index values less than 25 mph were rated high hazard, 25 to 50 mph as moderate hazard, and greater than 50 mph as low hazard. For purposes of this report, fire hazard rating is a quantified estimate of the potential fire behavior for a fuel type and is based on physical characteristics such as fuel arrangement, fuel load, and presence of elevated fuels. Fire hazard conditions are the fuel characteristics associated with a given fire hazard rating.

Fire hazard was evaluated for nine major forest types; however, our analysis primarily focused on short-interval, fire-adapted ecosystems. In Montana, these are the high/moderate-hazard ponderosa pine, Douglas-fir, and dry lower mixed-conifer forests where people and property are most at risk.

We collaborated with representatives from federal, state, tribal, and industrial land management entities to develop three treatment prescriptions for reducing fire hazard:

1. Thin from below. Remove trees up to 9 inches in diameter.
2. Fifty percent basal area removal. Remove the smaller half of basal area.
3. Comprehensive. Reserve a target basal area of 40 to 50 ft^2/ac, primarily composed of larger trees.

Fire hazard (i.e., crowning index) for each of the three treatments was evaluated immediately after treatment by using FFE. Treatment costs and revenues were estimated by using a harvest cost model and long-term databases maintained at the

University of Montana. Land management agencies and the private sector provided cost estimates for treating fuels resulting from management activities.

We used FVS to project posttreatment conditions forward 30 years for each of the treatment alternatives and then reevaluated crowning index again in 2030 by using FFE. Projection allowed us to evaluate the durability of hazard reduction treatments through time.

Montana has nearly 22.3 million acres of forest lands, 82 percent of which have a high/moderate fire hazard rating. Nearly 9.3 million acres are classified as short-interval, fire-adapted ecosystems. About 7.5 million acres (or 80 percent) of these rated high/moderate for crown fire hazard.

Our analysis showed that hazard reduction treatments differed dramatically in their potential to reduce crown fire hazard. The thin-from-below treatment only increased average crowning index in treated stands from 27 to 34 mph, moving only 13 percent of treated acres into the low-hazard category. The comprehensive treatment, in contrast, increased average crowning index to 82 mph, moving 90 percent of treated acres into a low-hazard condition.

We also found that the comprehensive prescription designed to reduce hazard and restore sustainable stand conditions would yield average positive net revenues of $675 per acre treated. Some stands would require expenditures, but the value of timber products removed would cover harvest, onsite fuel treatment, and haul costs on over half of the acres treated. In contrast, net revenues were always negative for the thin-from-below prescription, and negative for most acres treated with the 50-percent basal area removal approach.

Our reevaluation of crowning index in 2030 showed that the long-term effects of the various hazard reduction treatments continued to differ widely. Average crowning index following the thin-from-below treatment nearly reverted back to the high-hazard category by 2030. In contrast, the average crowning index for the comprehensive treatment decreased to 64 mph, still solidly in the low-hazard category. Long-term effects of the 50-percent basal area removal treatment were only moderately better than those of the thin-from-below treatment.

One striking effect associated with the two prescriptions aimed at removing small trees is that substantial acreages would again need hazard reduction treatment at the end of the 30-year period. Only 3 percent of the acres receiving the thin-from-below treatment and 10 percent receiving the 50-percent basal area removal treatment would remain in the low-hazard category in 2030. However, 73 percent of the acres treated with the comprehensive prescription would still have a low-hazard rating 30 years later.

Study results show that whether the fire problem is viewed from a hazard reduction, ecological condition, or financial standpoint, the comprehensive approach is superior to prescriptions that focus only on removing small trees. The comprehensive prescription achieves far greater hazard reduction immediately after treatment and is far less expensive to apply. It is also superior in terms of longevity and effectiveness.

Highlights

- Over 80 percent of all forested lands in Montana rated high/moderate for crown fire hazard.
- About 9.3 million acres of Montana forest land fell within short-interval, fire-adapted ecosystems, 7.5 million acres of which were high/moderate hazard.
- Alternative treatments differed dramatically in their effectiveness in reducing crown fire hazard.
- A comprehensive prescription designed to reduce hazard and restore sustainable structure was superior to prescriptions designed to remove smaller trees only.
- In dense, multistoried ponderosa pine–Douglas-fir stands (*Pinus ponderosa* Dougl. ex Laws.–*Pseudotsuga menziesii* (Mirb.) Franco) in western Montana, the comprehensive treatment increased crowning index an average of 68 mph, whereas the thin-from-below treatment only increased crowning index by 2 mph.
- Ninety percent of the acres receiving the comprehensive treatment rated low hazard following treatment, whereas only 13 percent rated low hazard following the thin-from-below treatment.
- The comprehensive prescription not only provided the greatest hazard reduction, it also yielded an average net revenue of $675 per acre from timber removed as a treatment byproduct.
- Over 70 percent of the acres receiving the comprehensive treatment remained low hazard 30 years after treatment. Only 3 percent of the acres receiving the thin-from-below treatment were rated low hazard 30 years later.

Contents

Introduction

Severe "fire years" in Montana in 1988 and 1994, and most recently in 2000 and 2003, illustrate the hazardous forest conditions that exist over large areas of the Montana landscape. The fires of 2000 are especially notable, not just in terms of acres burned, but particularly because of the significant damage to property and associated threats to people.

Four major fire seasons in just 16 years have intensified public and agency concerns about wildfire.

Four major fire seasons in just 16 years have intensified public and agency concerns about wildfire. There are now both the public support and political will for major initiatives to address this regional concern (Devlin 2001, Western Governors' Association 2001). However, planning to address fire hazard at a strategic level requires a fundamental understanding of the nature and scope of the problem. For example, what forest types and conditions are most vulnerable to fire? What kinds of treatments are most effective in reducing fire hazard, and how much do they cost? How durable are the effects of these treatments?

Absence of a detailed, systematic, and uniform forest inventory for all acres and ownerships has until now precluded a comprehensive analysis of fire hazard in Montana. However, recent availability of Forest Inventory and Analysis (FIA) data across all ownerships makes possible a strategic assessment of fire hazard at the statewide level and is the basis for the analysis that follows.

The overall goals of our project were to profile forest conditions and fire hazard in Montana and evaluate the potential effectiveness and costs of hazard reduction treatments. Specific objectives were to:

- Describe and quantify forest conditions in Montana and rate conditions for fire hazard.
- Develop treatment prescriptions and evaluate their effectiveness at reducing hazard, both now and 30 years into the future.
- Determine harvest and prescribed burning costs associated with treatment.
- Determine the potential revenue from timber products generated by the hazard reduction treatments.

Methods

The FIA data on the composition and condition of forest lands in Montana were obtained from the USDA Forest Service Interior West Forest Inventory and Analysis (IWFIA) program based in Ogden, Utah. This unit conducts permanent plot inventories in Montana and other Rocky Mountain states.

The National Forest System (NFS) inventory data used in this study were collected between 1993 and 1997 for western Montana, and between 1996 and 1998 for

eastern Montana, and included both nonreserved and reserved lands (i.e., wilderness). The inventory of non-NFS lands occurred between 1988 and 1989 and was conducted on nonreserved lands only. Thus National Park Service lands were not included in the inventory nor were reserved lands managed by the USDI Bureau of Land Management, U.S. Fish and Wildlife Service, state of Montana, or Confederated Salish and Kootenai Tribes.

The most important characteristics of IWFIA data are their uniformity and comprehensiveness. Although forest conditions can differ greatly, the IWFIA data set allows description and comparison within and across regions and ownerships by using common measures gathered through consistent, scientific sampling methods.

We worked with data from 1,936 sample plots in western Montana and 1,807 plots in eastern Montana. A sample plot was our basic unit of analysis. Each plot was regarded as a stand and typically represents about 6,000 acres of forest lands. Variables recorded at each sample plot fall into one of four categories:

- Location variables: owner, elevation, distance to road.
- Condition variables: condition class, slope, aspect, land use.
- Tree and stand variables: diameter, height, basal area, volume, species.
- Understory vegetation variables: cover of three vegetative layers, i.e., tree cover, shrub cover, forb cover; also grass cover.

Fire Hazard

Potential fire hazard was analyzed for each plot by using the Fire and Fuels Extension (FFE) (Beukema et al. 1997, Scott and Reinhardt 2001) to the Forest Vegetation Simulator (FVS) (Crookston and Havis 2002, Wykoff et al. 1982). This model (extension) estimates crown fire hazard based on tree, stand, and site characteristics, and expresses fire hazard and effects in terms of crowning index, torching index, and basal area mortality.

Crowning index, defined as the windspeed necessary for a fire that reaches the canopy to continue as a crown fire, was the primary variable used to report hazard in this study. Crowning index is primarily determined by canopy bulk density, which is the density of 1-hr fuels (i.e., <¼-in twigs and needles). Forest structures with low crowning indexes require relatively low windspeeds to maintain spreading crown fires, whereas structures with high crowning indexes are relatively resistant to crown fires. We defined high-hazard forest conditions as having a crowning index of <25 mph, moderate hazard from 25 to 50 mph, and low hazard >50 mph. Actual crowning index values should be interpreted cautiously because forest and weather conditions are variable. However, because modeling assumptions were the same for the three treatments evaluated, relative differences in crowning indexes

among posttreatment conditions are instructive. Once the crowning index was calculated for each plot, the entire inventory was sorted by various combinations of forest type, density, structure, region, and ownership to display fire hazard by the categories of interest. In addition, the FVS model was used to project forest conditions 30 years into the future (i.e., from 2000 to 2030), at which time fire hazard was again assessed by using FFE.

Forest Types

Conditions differ greatly across the millions of acres and approximately 7,000-ft elevation range of forest lands in Montana. We classified these diverse conditions into forest types that would be recognizable and meaningful to managers. We used a hierarchical model to assign each of the more than 3,700 FIA sample plots in Montana to one of nine forest types or one of two miscellaneous categories. Forest type assignments were based on majority (or plurality) basal area composition of key tree species and on habitat type (Pfister et al. 1977) criteria. Any plot not meeting minimal requirements for any of the nine forest type designations was classified as either "other" or "nonstocked," depending on specific attributes.

Density and Structure

The FIA plots (stands) were assigned to one of three density categories (low, moderate, or high) by using a three-step process. Data were first sorted by region (west vs. east of the Continental Divide) and then by forest type within region. Finally, density classes were formulated by subdividing the population of plots within each region/forest type combination into thirds based on the full range of basal area densities for that combination. Thus low-density conditions as classified for this analysis are likely higher than the low density for a given forest type based on historical conditions; instead they fall within the lowest one-third of existing densities for that forest type and region (e.g., ponderosa pine, east side).

Each FIA plot was assigned to one of four structural classes (scattered, one story, two story, or multistory). We formulated structural classes for each forest type primarily based on size class and basal area attributes. Five general size classes of trees were recognized: sapling (<5.0 in diameter at breast height [d.b.h.], pole (5 to 8.9 in d.b.h.), medium (9 to 14.9 in d.b.h.), large (15 to 19.9 in d.b.h.), and very large (>20.0 in d.b.h.). Plots with <25 ft^2/ac of basal area were assigned to scattered structures as such conditions are too open to recognize distinct layers or strata. Plots with only one recognizable size class were categorized as one-storied structures, plots with two distinct size classes were categorized as two-storied structures, and plots with three or more size classes were categorized as multistoried structures. A minimum basal area of 10 ft^2/ac was required for pole, medium, large,

or very large size classes to be recognized as an individual size class or stratum. For saplings, a minimum of 5 ft^2/ac was required to be recognized as a distinct size class.

Hazard Reduction Treatments

We focused our evaluation of fire hazard on short-interval, fire-adapted ecosystems. In Montana, these ecosystems are primarily composed of ponderosa pine (PP), Douglas-fir (DF), and dry lower mixed-conifer (DLMC) forest types. Short-interval, fire-adapted ecosystems were identified as highest priority for treatment in *Protecting People and Sustaining Resources in Fire-Adapted Ecosystems—A Cohesive Strategy* (USDA FS 2000, USDI 2001). Historically, frequent low-intensity fires were the primary agent that shaped these forests and kept them resistant to severe fires.

Although dense, multistoried conditions are a primary concern in short-interval, fire-adapted ecosystems, they are neither unexpected nor uncommon in the moist lower mixed-conifer, upper mixed-conifer, and spruce-fir forest types. Fires typically occur in these forests at relatively long intervals and burn with high severity when they do occur (Fischer and Bradley 1987). Wildfires in moister and higher elevation forests are not as often a direct threat to people or property and historically burned as mixed-intensity or stand-replacement events when they did occur (Fischer and Bradley 1987). Consequently, short-interval, fire-adapted forests were deemed highest priority for detailed evaluation by the technical contact team for this study.[1]

Three general types of hazard reduction treatments were evaluated. A common objective of all three is to reduce density and create a discontinuity in the vertical fuel profile by removing the ladder fuel component, typically composed of sapling- and pole-sized trees. One such approach is thinning from below to some given diameter limit, a treatment that has been widely recommended.[2,3] We used a diameter limit of 9 inches in this analysis. This treatment is hereafter referred to as TB9. Because the primary objective of the TB9 treatment is to reduce or remove the ladder fuel layer, rather than substantially reduce overall stand density, this treatment was only applied to stands that had greater than 50 ft^2/ac of trees larger than

[1] The technical contact team served in an advisory capacity for this study. Members had expertise in the areas of inventory, fire management, and hazard reduction treatments, and represented state and federal government, Indian tribes, forest industry, and private landowners.

[2] Babbitt, B. 1997. A coordinated campaign: fight fire with fire. Speech delivered at Boise State University, Boise, Idaho. U.S. Department of the Interior, Washington, DC.

[3] Dombeck, M. 1997. Statement to Senate Committee on Energy and Natural Resources, Feb. 25, 1997. Washington, DC: U.S. Congress.

9 in. Indeed, a primary reason for selecting the thin-from-below approach is to avoid cutting larger trees or creating open stand conditions. Put another way, any stand that would not have at least 50 ft^2/ac of basal area remaining after receiving the TB9 treatment was not considered for treatment.

A second approach is to remove some given percentage of the existing basal area (e.g., 33 to 50 percent) from the smallest trees on up (Martin 2000). A target of 50-percent removal was used in this analysis. This treatment is hereafter referred to as 50-percent BA. This approach tempers potential criticism associated with cutting larger trees in a stand or creating open stand conditions. Hence, any stand that would not have at least 50 ft^2/ac of basal area remaining after receiving the 50-percent BA treatment was not considered for treatment.

A third general approach focuses on restoring sustainable structure (and ultimately ecological function), and therefore focuses on the trees to leave in terms of a target density, diameter distribution, and species composition (Fiedler et al. 1999). Trees are marked for leave to a target basal area density of 40 to 50 ft^2/ac in the sizes, numbers, species, and juxtaposition that will go furthest toward restoring a sustainable structure, given existing stand conditions. This ecologically based prescription preferentially reserves larger ponderosa pine (*Pinus ponderosa* Doug. ex Laws.) and western larch (*Larix occidentalis* Nutt.), which are especially fire resistant. It also reduces density sufficiently to induce regeneration of shade-intolerant ponderosa pine, promote development of large-diameter trees, and increase survival and vigor of old-growth trees (Fiedler 2000, Fiedler et al. 1988). Most of the 40- to 50-ft^2/ac target reserve density is composed of larger trees, although some trees are marked for leave throughout the diameter distribution (if available) to provide large-tree recruits for the future. A low thinning is used to remove small-tree ladder fuels, and improvement/selection cutting is applied in the mid and upper canopy to reduce crown fire hazard, remove late-successional species (if present), and promote regeneration of ponderosa pine or western larch. This treatment is hereafter referred to as the comprehensive restoration treatment or CR.

All three prescriptions were applied to the PP, DF, and DLMC forest types. The TB9 and 50-percent BA prescriptions were applied similarly in all three forest types. However, the CR treatment prescription differed slightly among types, with a target reserve density of 40, 45, or 50 ft^2/ac for the PP, DLMC, and DF forest types, respectively. The target reserve density could not always be retained because of existing diameter distributions and hazard reduction considerations. For example, somewhat lower reserve densities (20 to 40 ft^2/ac) occasionally resulted in the DF type in stand conditions with relatively small numbers of larger trees. Although all large and medium-sized trees were retained in these cases, the summed density of

all reserved trees was less than the target because the basal area of small trees that could be reserved was capped at 2.5 ft^2/ac for 4- to 8-in trees and 0.5 ft^2/ac for 0- to 4-in trees, respectively, for hazard reduction reasons.

Treatment Costs and Product Revenues

We did not consider treatment costs or potential timber product revenues when selecting or developing the alternative hazard reduction treatments for this study. The treatments we evaluated are either commonly used for hazard reduction or were designed specifically to reduce hazard and enhance sustainability. However, because cost is a major factor influencing the potential implementation of hazard reduction treatments, we analyzed costs after the prescriptions were developed and modeled. In calculating net revenue, we examined both treatment cost and the potential value of timber generated as a byproduct of treatments.

Treatment costs—
Costs associated with implementing hazard reduction treatments include costs of removing timber to reduce fuel loading, slashing activity fuels, and prescribed burning of slash. Treatment units were assumed to be operational in size (>20 ac). We estimated harvest and haul costs by using a recently completed predictive logging cost model applicable to hazard reduction and restoration treatments in Montana (BBER 2001a, Keegan et al. 2002). We assumed treatments would occur on sites already accessed; therefore, no road-building costs were included in the analyses. Data gathered from land management agencies and the private sector provided an additional basis for estimating costs associated with treating activity fuels. Estimated costs for hand piling and burning trees less than 5 in d.b.h. ranged from $50 to $280 per acre depending on tree density; cost of removing unmerchantable trees 5 in d.b.h. and greater ranged from under $100 per acre to over $1,000 per acre, depending on stand condition and logging system.

Timber product values—
Previous work shows that comprehensive prescriptions designed to reduce hazard and restore structure require removal of trees ranging from 4 to >20 inches in diameter (Fiedler et al., 1999, 2001). Trees in this size range have two major product uses, sawtimber and pulpwood (Keegan et al. in press). Sawtimber is defined as trees that are of a size and quality suitable for lumber production. In Montana, sawtimber includes trees ≥10 in d.b.h. The major uses of sawtimber in Montana are saw logs for lumber production and veneer logs for plywood. Pulpwood is timber used to produce chips for pulp manufacture, and in Montana is generally composed of material <10 in d.b.h.

We developed sawtimber tree values for 1-in d.b.h. classes by major species or species' groups from an extensive log price data system maintained by the University of Montana Bureau of Business and Economic Research (BBER 2001b) and from a sawmill simulation model (Wagner et al. 1998, 2000).

We analyzed product values under a sawtimber market scenario based on lumber and plywood prices from 1997 through 1999. This was a period of mixed conditions, with very strong markets in the first half of 1997 and most of 1999, and substantially weaker markets in 1998 owing to the Asian financial crisis. Historically, the market for roundwood pulpwood has been very sporadic, and at times, nonexistent. For this reason, we assumed 1997–99 sawtimber market conditions in our analysis, without a pulpwood market. Adjustments also were made to reflect lower values for certain species in eastern Montana.

The relationship between milling capacity and the volume of timber available to the industry was assumed to remain constant under all market conditions. If a significant proportion of acres rated high/moderate for fire hazard were treated over a short period, large volumes of additional material could potentially come on the market, thus dampening prices. However, we assumed that increases in harvested timber volume would phase in gradually and reach a sustainable level. This in turn would lead to a gradual and commensurate increase in industry size.

Results and Discussion

Forest Types

Our analysis of FIA data for Montana shows that there were approximately 22.3 million acres of forest land in the state, 21.5 million of which were forested (table 1). The three forest types, PP, DF, and DLMC, of greatest management concern in terms of fire hazard collectively occupied 9.3 million acres. About 775,000 acres were classified as "other" (OT) as they did not meet criteria for any individual forest type. Five of the forest types (PP, DF, lodgepole pine, moist lower mixed conifer, and spruce-fir) comprised at least 1 million acres each of forest land in Montana (table 1). Detailed breakdowns of acreages of forest types by region, ownership, density, and structure are shown in appendix tables 7a through 7d.

The federal government owns 14.8 million acres (69 percent) of the 21.5 million forested acres in Montana, 25 percent is privately owned, and the remaining 6 percent is in other ownership, which includes tribal and state lands (appendix table 8).

No clear patterns in forest conditions (i.e., density or structure) could be discerned by ownership alone. However, some interesting observations about the ownership of different forest types did surface in our analysis (appendix table 7b).

Table 1—Acreages of major forest types in Montana

Forest type	Forest land area
	Acres
Ponderosa pine	2,841,185
Douglas-fir	6,176,632
Dry lower mixed conifer	265,688
Western larch	533,637
Lodgepole pine	4,344,061
Moist lower mixed conifer	1,375,005
Upper mixed conifer	693,436
Spruce-fir	3,867,859
Timberline	588,257
Other	774,466
Total forested acres	21,460,226
Nonstocked	814,067
Total forest land	22,274,293

Table 2—Basal area ranges for low-, moderate-, and high-density classes, by fire-adapted forest type and geographic region

	Basal area		
Forest type[a]	Low	Moderate	High
		Ft²/acre	
West of the Continental Divide:			
PP	<50	50–100	>100
DF	<90	90–150	>150
DLMC	<80	80–130	>130
East of the Continental Divide:			
PP	<40	40–75	>75
DF	<80	80–130	>130
DLMC	<60	60–130	>130

[a] Fire-adapted forest types include ponderosa pine (PP), Douglas-fir (DF), and dry lower mixed conifer (DLMC).

For example, only about half (54 percent) of Montana's 9.3 million acres of short-interval fire-adapted forests (PP, DF, DLMC types) are federally owned, whereas 86 percent of upper mixed-conifer, 90 percent of spruce-fir, and 98 percent of timberline forests are owned by the federal government.

Density and Structure

The ranges of basal area densities that were classified as high, moderate, and low differed among forest types and geographic regions (west and east of the Continental Divide) (appendix table 9). Basal area density ranges for the PP, DF, and DLMC types are shown in table 2 to provide a frame of reference as to "How dense is dense?"

The 21.5 million forested acres in the state were classified within one of four structural types: scattered, one storied, two storied, or multistoried, with <1 percent of this total classified as having no structure. Approximately 9.5 million acres, or 44 percent of the forested acres, occurred in multistoried structures. About 28, 19, and 9 percent occurred in two-storied, one-storied, and scattered structures, respectively (appendix table 7).

Analysis of crown fire hazard shows that 42 percent of Montana's forests were classified as high hazard, about 40 percent as moderate hazard.

Fire Hazard: Existing Conditions

Results of our statewide analysis of crown fire hazard shows that 42 percent of Montana's forests were classified as high hazard, about 40 percent as moderate hazard, and only 18 percent as low hazard, based on crowning index (fig. 1). Fire hazard ratings were similar for forest lands located west and east of the Continental Divide. About 39 percent of the forest lands west of the Divide were rated high hazard, about 45 percent were rated moderate, and approximately 16 percent were low hazard. Comparable numbers for forest lands east of the Divide were 45, 36, and 19 percent, respectively.

Existing fire hazard conditions in the 9.3 million acres of short-interval, fire-adapted forests approximated those for the state as a whole. Thirty-five percent of the acres of fire-adapted forests were rated high hazard, 45 percent as moderate hazard, and 20 percent as low hazard (fig. 2). Of the nearly 5 million acres of PP, DF, and DLMC on federal land, 83 percent have a high/moderate fire hazard rating. This is in line with the fire hazard rating for these forest types across all ownerships, where 80 percent of short-interval, fire-adapted forests have a high/moderate fire hazard rating.

Average crowning index values by region, ownership, density, and structure are shown in appendix table 10. The trends in crowning index across density and structural classes were especially notable. For example, looking at all forest types combined, average crowning index declined (i.e., hazard increased) across the range

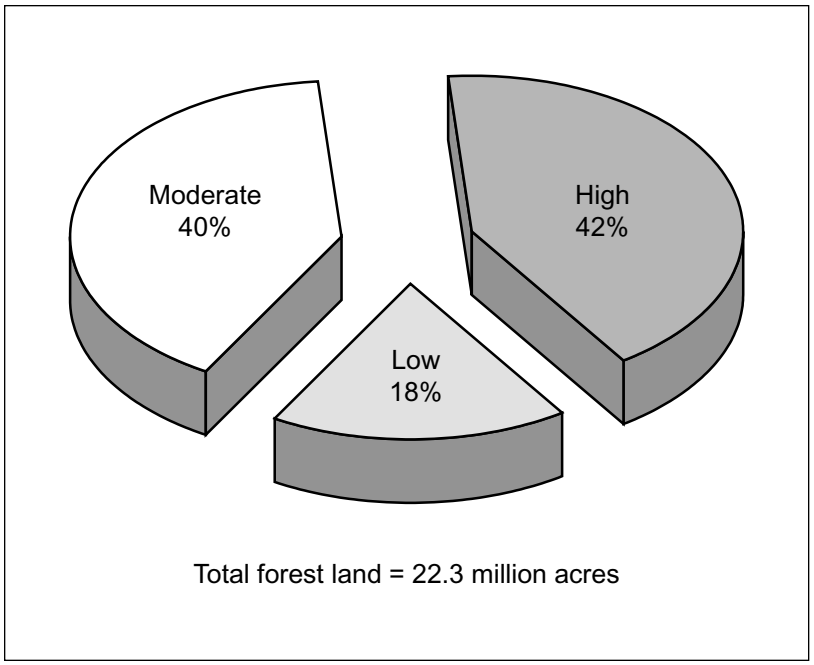

Figure 1—Proportion of Montana's forest land by fire hazard rating.

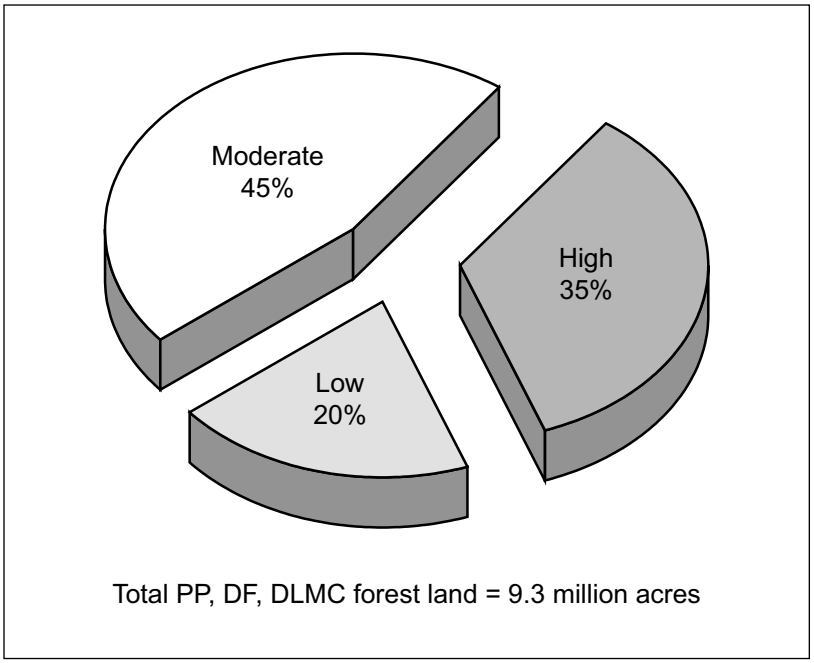

Figure 2—Proportion of Montana's short-interval, fire-adapted forest types (i.e., ponderosa pine (PP)/Douglas-fir (DF)/dry lower mixed conifer (DLMC)) by fire hazard rating.

of densities from 47 at low density to 29 at moderate density, to 21 at high density. Similarly, average crowning index declined (and hazard increased) with increasing complexity in stand structure, from 34 to 32 to 25 for one-, two-, and multistoried structures, respectively.

Stand density is a particularly important attribute influencing crowning index.

As the previous example shows, stand density is a particularly important attribute influencing crowning index. The strong effect of density is demonstrated in the following example. In stands with multistoried structures, 74 percent were rated high hazard if they were also in the high-density category, whereas only 26 percent of moderate-density stands and 0 percent of low-density stands in this structural class received a high-hazard rating. The importance of density to crowning index is not unexpected, given that the calculation of crowning index within FFE is primarily dependent on canopy bulk density.

Structure also had a substantial effect on crowning index in the 9.3 million acres of short-interval, fire-adapted forests. For example, in high-density conditions, 74 percent of the stands with multistoried structures were rated high hazard, where-as only 49 and 36 percent of two- and one-storied stands received a similar rating, respectively.

Fire Hazard: Treatment Effectiveness

Short-term effects on fire hazard—
Hazard reduction treatments were evaluated for effectiveness if applied to the 7.5 million acres of forests with high/moderate fire hazard in short-interval, fire-adapted ecosystems (PP, DF, and DLMC forest types). Our analysis showed that both average crowning index and the number of potentially treatable acres differed by prescription.

The effectiveness of treatments in reducing fire hazard ranged from modest for the TB9 treatment to dramatic for the CR treatment.

The effectiveness of treatments in reducing fire hazard (increasing crowning index) ranged from modest for the TB9 treatment to dramatic for the CR treatment (table 3). The TB9 treatment only increased average crowning index 7 mph, whereas the CR treatment created a 56-mph increase. The average crowning index of 34 resulting from the TB9 treatment still left most stands in the moderate fire hazard range, and only 13 percent of treated acres moved to low hazard (table 3). The CR treatment, in contrast, increased average crowning index to 82 mph, well into the low-hazard range.

The number of forested acres potentially treatable differed as a result of differential silvicultural constraints placed on the three prescriptions, leading to slight differences among pretreatment crowning index values (table 3). An example of the constraints and their effects on acres treated can be seen in the differences between the TB9 and CR treatments. The TB9 prescription could be

Table 3—Effects of hazard reduction treatments in fire-adapted forest types[a]

Hazard reduction treatment	Pretreatment crowning index	Posttreatment crowning index	Treated acres rated low hazard posttreatment	High/moderate hazard acres treated
	- - - - - - Mph (SD)[b] - - - - - -		*Percent*	*Million acres*
Thin from below (TB9)	27 (9.5)	34 (14.9)	13	5.1
50-percent basal area removal (50-percent BA)	25 (9.0)	50 (18.9)	44	5.2
Comprehensive restoration (CR)	26 (9.5)	82 (31.7)	90	6.4

[a] Fire-adapted forest types include ponderosa pine (PP), Douglas-fir (DF), and dry lower mixed conifer (DLMC).

[b] SD = standard deviation.

applied to 5.1 million acres of the 7.5 million acres rated high/moderate hazard, whereas the CR treatment could potentially be applied to as many as 6.4 million acres. The lower acreage associated with the TB9 treatment primarily arises from restrictions to cutting in stands that would not have sufficient basal area remaining if all trees below 9 in d.b.h. were cut (e.g., a PP stand with no trees >8 in d.b.h., or a DLMC stand with only 10 ft^2/acres of basal area in trees >9 in). The CR treatment could still be applied in some of these stands as long as the target reserve basal area could be achieved or sufficient trees were available to serve as a seed source for regenerating a new age class.

The long-term effects of the various fire-hazard treatments differed greatly. However, the effectiveness of all hazard reduction treatments diminished somewhat through time.

Long-term effects on fire hazard—

Our evaluation of crowning index in 2030 showed that the long-term effects of the various fire-hazard treatments differed greatly, depending on which prescription was implemented. However, the effectiveness of all hazard reduction treatments diminished somewhat through time.

Average crowning index following the TB9 treatment reverted from moderate hazard (34 mph) in 2000 nearly back to the high hazard category in 2030 (table 4). Average crowning index for the CR treatment changed the most (numerically) over the 30-year period, from 82 to 64 mph, but still remained solidly in the low hazard category (table 4). Changes associated with the 50-percent BA treatment were intermediate to the other two treatments.

Changes in crowning index values for two of the three prescriptions indicate that substantial acreages would again need hazard reduction treatment at the end of the 30-year period. Only 3 percent of the acres receiving the TB9 treatment and 10 percent receiving the 50-percent BA treatment would remain in the low hazard

Table 4—Immediate (2000) and long-term (after 30 years) effects of hazard reduction treatments in fire-adapted forest types[a]

Hazard treatment reduction	Average crowning index immediately after treatment	Average crowning index 30 years after treatment	Treated acres rated low hazard 30 years after treatment
	Mph (SD)[b]		*Percent*
Not treated	26 (9.5)	26 (7.4)	<1
Thin from below (TB9)	34 (14.9)	30 (9.0)	3
50-percent basal area removal (50-percent BA)	50 (18.9)	38 (9.9)	10
Comprehensive restoration (CR)	82 (31.7)	64 (22.4)	73

[a] Fire-adapted forest types include ponderosa pine (PP), Douglas-fir (DF), and dry lower mixed conifer (DLMC).

[b] SD = standard deviation.

category in 2030 (table 4). Meanwhile, 73 percent of the acres treated under the CR prescription would retain a low hazard rating 30 years after initial treatment.

The distribution of acres by crowning index values before treatment in 2000, after treatment in 2000, and in 2030 (fig. 3) shows that only the CR prescription provided lasting hazard reduction for treated stands. Differences are striking and further illustrate the relative short- and long-term ineffectiveness of prescriptions aimed only at removing small trees.

Financial Aspects of Hazard Reduction Treatments

More than half of the acres treated with the CR prescription yielded a value in timber (as treatment byproduct) that exceeded all onsite hazard treatment costs.

The three hazard reduction treatments differed greatly in terms of the volumes and value of timber products recovered in the process of treatment implementation. Based on 1997–99 market conditions, applying the TB9 prescription required an average expenditure of $669 per acre (table 5), and all acres treated with this prescription required expenditure to underwrite treatment costs (table 6, fig. 4). Application of the 50-percent BA prescription required an average expenditure of $287 per acre. A small proportion (20 percent) of the acres yielded timber product values sufficient to cover treatment costs. Applying the CR treatment prescription to those short-interval, fire-adapted forest acres with a high/moderate fire hazard rating yielded an average revenue of $675 per acre treated (table 5). The range of revenues was substantial, with some stands costing over $1,000 per acre to treat and others yielding positive net revenues of more than $2,000 per acre (fig. 4). More than half of the acres treated with the CR prescription yielded a value in timber (as treatment byproduct) that exceeded all onsite hazard treatment costs (table 6, fig. 4).

Net revenues (+ or -) associated with implementing a given prescription differed substantially between forests located west and east of the Continental Divide.

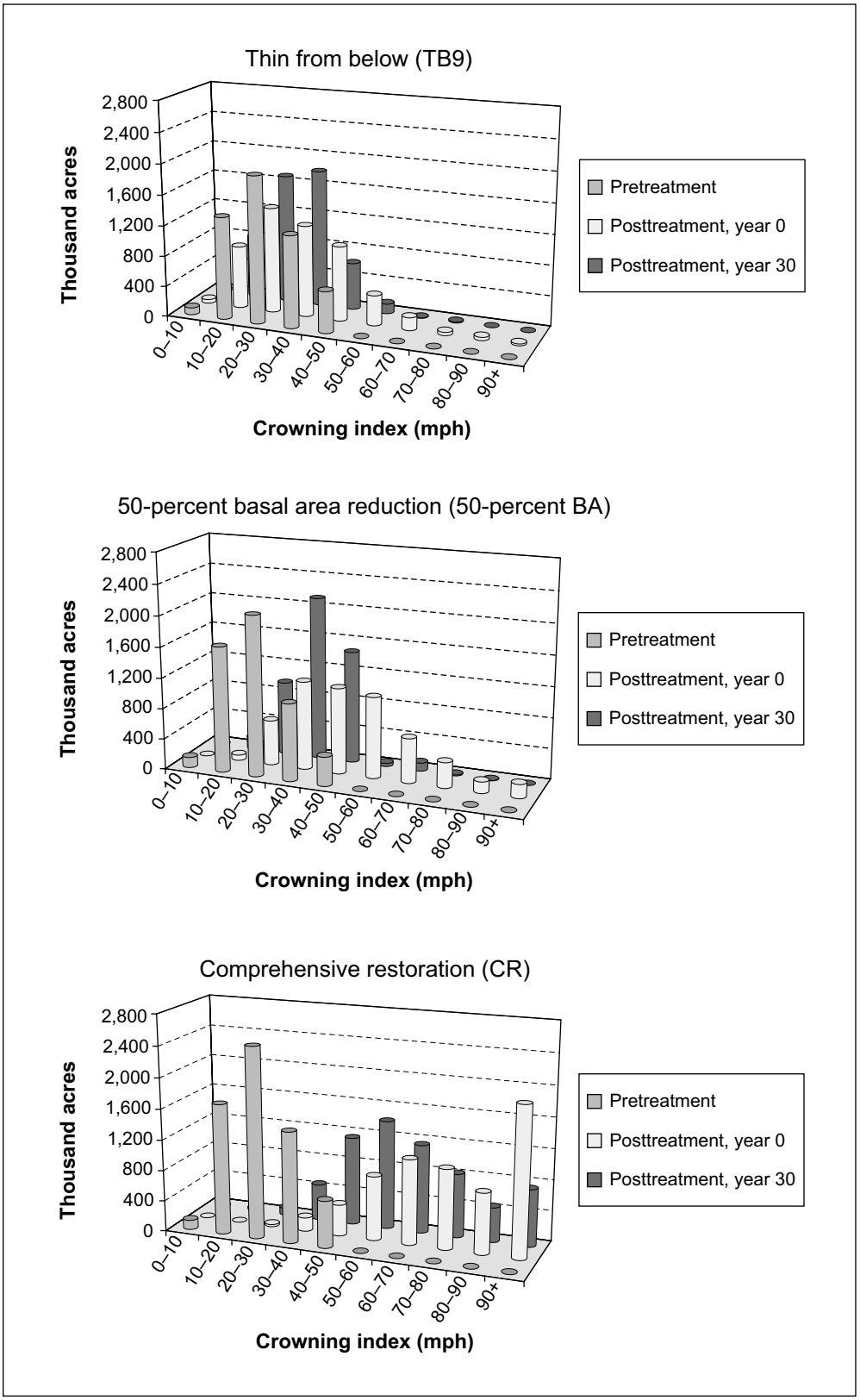

Figure 3—Distribution of acres by crowning index values pretreatment, posttreatment year 0, and posttreatment year 30, for three hazard reduction treatments.

Table 5—Net revenues per acre by hazard reduction treatment for fire-adapted forest types and 1997–99 market conditions[a]

Hazard reduction treatment	Statewide	West side	East side
Thin from below (TB9)	-$669	-$743	-$577
50-percent basal area removal (50-percent BA)	-$287	-$266	-$311
Comprehensive restoration (CR)	$675	$1,103	$196

[a]Fire-adapted forest types include ponderosa pine (PP), Douglas-fir (DF), and dry lower mixed conifer (DLMC).

Table 6—Percentage of treated acres with positive net revenues by hazard reduction treatment for fire-adapted forest types and 1997–99 market conditions[a]

Hazard reduction treatment	Statewide	West side	East side
		Percent	
Thin from below (TB9)	0	0	0
50-percent basal area removal (50-percent BA)	20	23	17
Comprehensive restoration (CR)	51	61	40

[a]Fire-adapted forest types include ponderosa pine (PP), Douglas-fir (DF), and dry lower mixed conifer (DLMC).

Stands west of the Divide had higher pretreatment volumes; therefore, substantially higher volumes of trees with commercial value were removed to achieve desired objectives. As a result, application of the CR treatment netted an average of $900 more per acre in west-side forests than east-side forests (table 5). Under the CR treatment, timber product values exceeded treatment costs on 61 percent of the west-side acres, compared to only 40 percent east of the divide (table 6).

Because stands in western Montana also supported a greater number of small trees with little or no product value, the average cost of applying the TB9 treatment was $166 per acre higher ($743 vs. $577) in west- versus east-side forests (fig. 5, table 5). Conversely, there was little difference in costs ($311 vs. $266 per acre) west and east of the Continental Divide for the 50-percent BA treatment (table 5).

Several market conditions were evaluated, and different market assumptions resulted in different costs and revenues associated with the alternative treatment prescriptions. However, fundamental differences among treatments did not change under the various market scenarios. For example, inclusion of a roundwood pulpwood market—which provides an improved outlet for smaller material—improved the financial aspect of all the treatments. Under the pulpwood scenario, the TB9 and 50-percent BA treatments required smaller (though still substantial) expenditures to implement, whereas the CR prescription yielded even greater positive revenues.

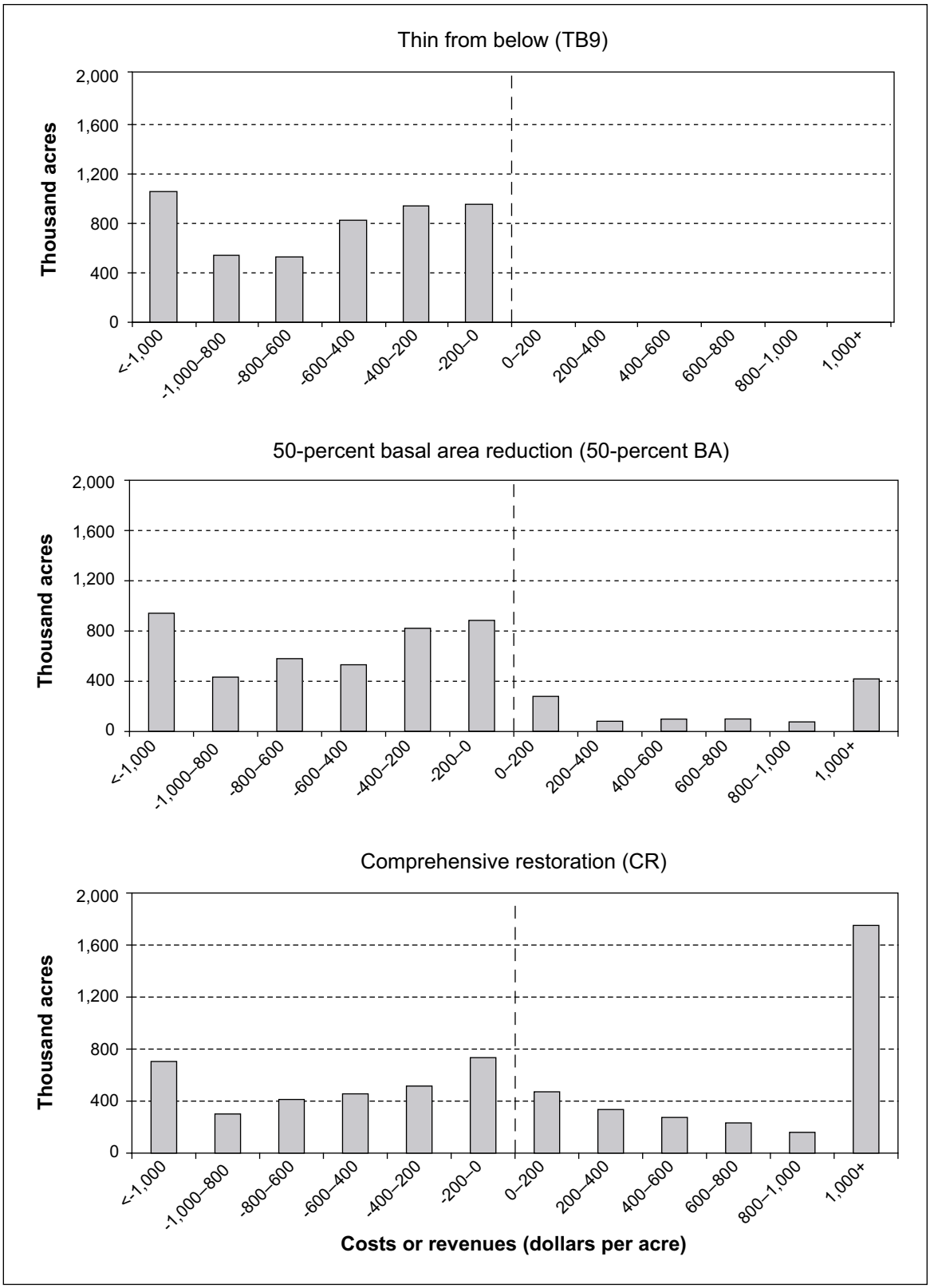

Figure 4—Distribution of acres by net revenue and hazard reduction treatment for high/moderate hazard conditions in ponderosa pine, Douglas-fir, dry lower mixed conifer forest types (1997–1999 market conditions).

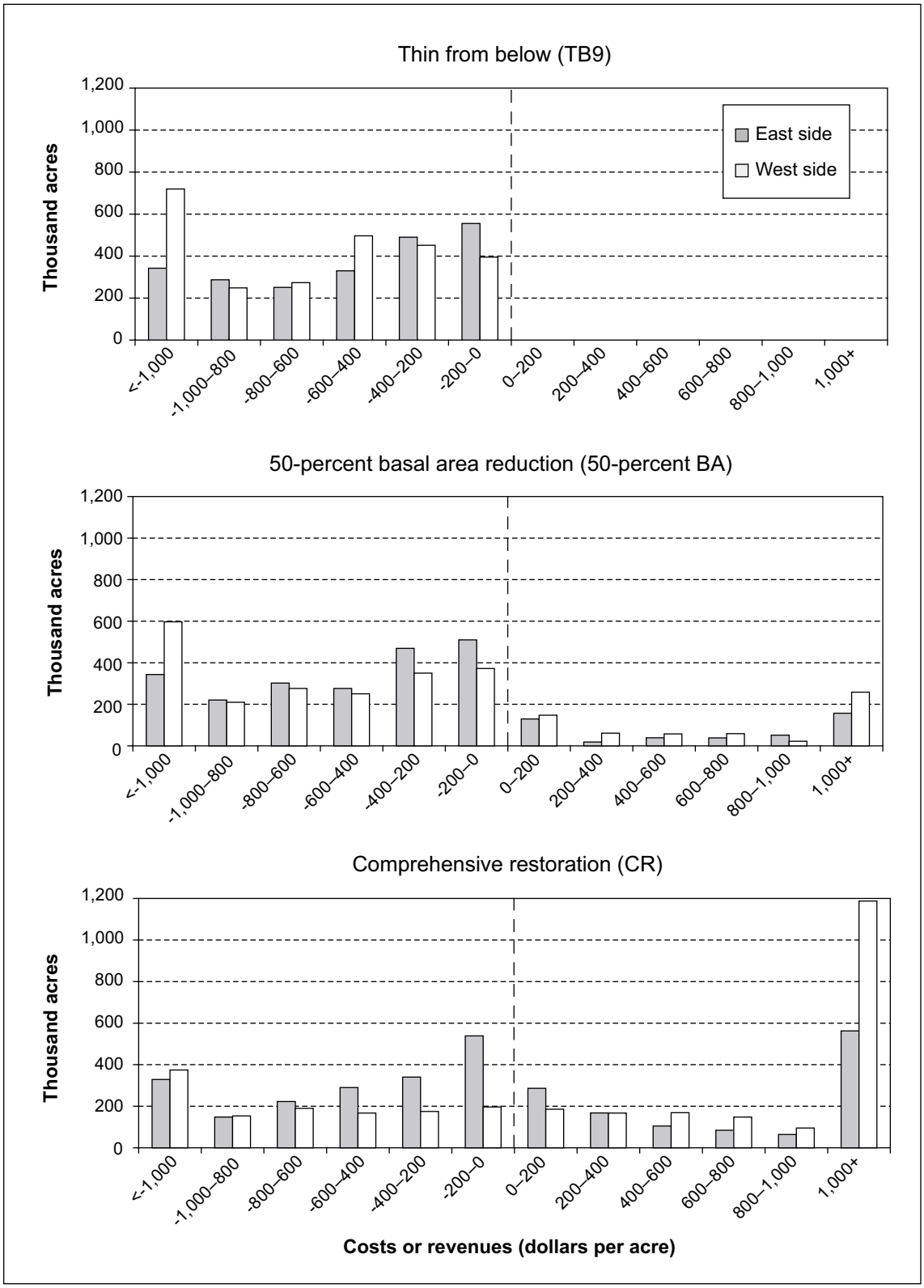

Figure 5—Distribution of acres by net revenue and hazard reduction treatment for high/moderate hazard conditions in ponderosa pine, Douglas-fir, dry lower mixed-conifer forest types, east and west of the Continental Divide (1997–99 market conditions).

Conclusion

It is critical that managers carefully review options before applying hazard reduction treatments. Considerable money and effort can be expended with little improvement in fire hazard or ecological condition.

It is critical that managers carefully review options before applying hazard reduction treatments. Considerable money and effort can be expended with little improvement in fire hazard or ecological condition. For example, applying the TB9 treatment that removes only trees 9 in and smaller from hazardous stand conditions is expensive, yet has little effect on lowering crown fire hazard. In the dense, two- and multistoried stands in western Montana where fire hazard is greatest, average crowning index was only 2 to 3 mph higher after receiving the TB9 treatment than before. These results underscore the importance of evaluating pre- and posttreatment conditions (stand tables) for crowning index during the process of prescription development.

Our results demonstrate that a treatment approach that focuses on restoring sustainable forest structure (and ultimately ecological function) in fire-adapted forests is often dramatically superior to thin-from-below treatments in reducing crown fire hazard. The CR approach evaluated in this analysis identifies a desired future range of conditions, evaluates the existing stand, and reserves trees in the sizes, numbers, and species that make the most progress toward these desired conditions. Put another way, trees that do not contribute to this objective are removed from the stand—they are a byproduct of the CR treatment. Hazard reduction prescriptions, in contrast, commonly start with the premise that fire hazard is essentially a one-dimensional, small-tree problem, and therefore prescribe the removal of variable amounts of small trees to address it. However, our evaluation of crown fire hazard following treatment shows that these small-tree removal prescriptions do not achieve their stated objective. Although removing small trees is a necessary part of any effort to reduce hazard, this analysis clearly shows that by itself, it is not sufficient.

The CR treatment, with multiple ecologically based objectives, moves 90 percent of treated acres into a low-hazard condition following treatment. In addition, removing late-successional species and reducing density sufficiently to induce seral species regeneration (and enhance sustainability) commonly require cutting some medium-sized and larger trees with commercial value, which on average yield enough revenue to cover treatment costs. Hazard reduction effects are also longer lasting, with over 70 percent of treated stands remaining in a low-hazard condition 30 years after treatment.

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Metric Equivalents

When you know:	Multiply by:	To get:
Inches (in)	2.54	Centimeters
Feet (ft)	.3048	Meters
Miles per hour (mph)	1.609	Kilometers per hour
Acres (ac)	.405	Hectares
Square feet (ft^2)	.0929	Square meters
Square feet per acre (ft^2/ac)	.229	Square meters per hectare

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Table 7a—Acres by region, forest type, density, structure

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Acres										
Montana:											
Structure—											
No structure	27,468	17,466	NA	NA	NA	12,573	NA	6,381	11,691	11,333	86,912
Scattered	487,363	454,678	124,611	259,645	28,832	85,720	29,873	318,471	71,851	70,499	1,931,543
One story	263,984	524,393	268,847	2,320,671	35,673	125,874	95,546	279,396	62,040	111,386	4,087,810
Two story	1,120,792	1,389,267	121,088	1,513,052	86,486	319,839	198,750	749,459	171,044	269,536	5,939,313
Multistoried	941,578	3,790,828	19,091	250,693	114,697	830,999	369,267	2,514,152	271,631	311,712	9,414,648
Total	2,841,185	6,176,632	533,637	4,344,061	265,688	1,375,005	693,436	3,867,859	588,257	774,466	21,460,226
Density—											
Low	1,114,917	2,152,151	191,595	1,415,442	74,869	546,487	220,753	1,290,458	287,521	259,343	7,553,536
Moderate	861,810	1,925,413	165,900	1,412,681	105,976	461,943	241,253	1,310,343	113,838	267,809	6,866,966
High	864,458	2,099,068	176,142	1,515,938	84,843	366,575	231,430	1,267,058	186,898	247,314	7,039,724
Total	2,841,185	6,176,632	533,637	4,344,061	265,688	1,375,005	693,436	3,867,859	588,257	774,466	21,460,226
West of the Continental Divide:											
Structure—											
No structure	5,808	17,466	NA	NA	NA	12,573	NA	6,381	NA	NA	42,228
Scattered	96,518	281,948	124,611	125,334	19,170	61,042	24,710	197,828	24,393	NA	955,554
One story	49,989	293,841	268,847	925,992	21,349	114,565	56,483	168,494	23,305	NA	1,922,865
Two story	222,303	765,746	121,088	743,312	57,895	271,452	140,402	412,516	77,643	20,374	2,832,731
Multistoried	257,203	2,244,050	19,091	86,745	95,273	709,524	257,625	1,463,165	90,455	42,509	5,265,640
Total	631,821	3,603,051	533,637	1,881,383	193,687	1,169,156	479,220	2,248,384	215,796	62,883	11,019,018
Density—											
Low	225,294	1,279,848	191,595	583,363	59,708	414,179	145,940	788,008	125,168	20,218	3,833,321
Moderate	210,939	1,187,226	165,900	635,562	74,797	419,427	172,054	740,294	55,477	17,649	3,679,325
High	195,588	1,135,977	176,142	662,458	59,182	335,550	161,226	720,082	35,151	25,016	3,506,372
Total	631,821	3,603,051	533,637	1,881,383	193,687	1,169,156	479,220	2,248,384	215,796	62,883	11,019,018
East of the Continental Divide:											
Structure—											
No structure	21,660	NA	NA	NA	NA	NA	NA	NA	11,691	11,333	44,684
Scattered	390,845	172,730	NA	134,311	9,662	24,678	5,163	120,643	47,458	70,499	975,989
One story	213,995	230,552	NA	1,394,679	14,324	11,309	39,063	110,902	38,735	111,386	2,164,945

Table 7a—Acres by region, forest type, density, structure (continued)

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
						Acres					
Two story	898,489	623,521	NA	769,740	28,591	48,387	58,348	336,943	93,401	249,162	3,106,582
Multistoried	684,375	1,546,778	NA	163,948	19,424	121,475	111,642	1,050,987	181,176	269,203	4,149,008
Total	2,209,364	2,573,581	NA	2,462,678	72,001	205,849	214,216	1,619,475	372,461	711,583	10,441,208
Density—											
Low	889,623	872,303	NA	832,079	15,161	132,308	74,813	502,450	162,353	239,125	3,720,215
Moderate	650,871	738,187	NA	777,119	31,179	42,516	69,199	570,049	58,361	250,160	3,187,641
High	668,870	963,091	NA	853,480	25,661	31,025	70,204	546,976	151,747	222,298	3,533,352
Total	2,209,364	2,573,581	NA	2,462,678	72,001	205,849	214,216	1,619,475	372,461	711,583	10,441,208

NA = no plots recorded.

[a] Forest type abbreviations are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, S/F = spruce/fir, TL = timberline.

Table 7b—Acres by ownership, forest type, density, structure in Montana

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Acres										
Federal:											
Structure—											
No structure	10,128	17,466	NA	NA	NA	12,573	NA	6,381	11,691	11,333	69,572
Scattered	211,936	269,181	90,487	167,167	15,937	61,645	12,847	286,080	71,851	40,370	1,227,501
One story	53,899	335,708	174,641	1,975,345	NA	74,386	82,821	238,250	62,040	22,079	3,019,169
Two story	318,209	885,940	77,499	1,268,220	48,765	216,292	172,518	657,836	171,044	77,461	3,893,784
Multistoried	353,460	2,397,635	12,573	203,301	62,325	548,041	325,424	2,305,797	261,276	126,258	6,596,090
Total	947,632	3,905,930	355,200	3,614,033	127,027	912,937	593,610	3,494,344	577,902	277,501	14,806,116
Density—											
Low	395,746	1,383,147	140,286	1,095,069	22,318	388,578	187,389	1,182,900	287,521	113,433	5,196,387
Moderate	277,114	1,283,409	118,485	1,277,784	66,629	364,277	230,175	1,229,864	107,643	81,389	5,036,769
High	274,772	1,239,374	96,429	1,241,180	38,080	160,082	176,046	1,081,580	182,738	82,679	4,572,960
Total	947,632	3,905,930	355,200	3,614,033	127,027	912,937	593,610	3,494,344	577,902	277,501	14,806,116
Private:											
Structure—											
No structure	17,340	NA	NA	NA	NA	NA	NA	NA	NA	NA	17,340
Scattered	235,977	156,895	26,364	79,578	12,895	18,038	17,026	26,354	NA	18,172	591,299
One story	184,142	169,071	76,341	269,914	26,836	39,205	11,002	26,079	NA	61,539	864,129
Two story	652,159	442,920	30,358	192,714	28,217	82,259	22,786	61,555	NA	163,416	1,676,384
Multistoried	432,938	1,072,575	NA	40,940	33,419	206,791	30,919	137,994	4,160	153,406	2,113,142
Total	1,522,556	1,841,461	133,063	583,146	101,367	346,293	81,733	251,982	4,160	396,533	5,262,294
Density—											
Low	593,320	657,129	41,826	275,418	45,753	130,839	28,195	86,164	NA	101,632	1,960,276
Moderate	482,076	549,850	39,895	97,210	31,913	88,735	5,362	50,318	NA	158,681	1,504,040
High	447,160	634,482	51,342	210,518	23,701	126,719	48,176	115,500	4,160	136,220	1,797,978
Total	1,522,556	1,841,461	133,063	583,146	101,367	346,293	81,733	251,982	4,160	396,533	5,262,294
Other:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	39,450	28,602	7,760	12,900	NA	6,037	NA	6,037	NA	11,957	112,743
One story	25,943	19,614	17,865	75,412	8,837	12,283	1,723	15,067	NA	27,768	204,512

Table 7b—Acres by ownership, forest type, density, structure in Montana (continued)

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Acres										
Two story	150,424	60,407	13,231	52,118	9,504	21,288	3,446	30,068	NA	28,659	369,145
Multistoried	155,180	320,618	6,518	6,452	18,953	76,167	12,924	70,361	6,195	32,048	705,416
Total	370,997	429,241	45,374	146,882	37,294	115,775	18,093	121,533	6,195	100,432	1,391,816
Density—											
Low	125,851	111,875	9,483	44,955	6,798	27,070	5,169	21,394	NA	44,278	396,873
Moderate	102,620	92,154	7,520	37,687	7,434	8,931	5,716	30,161	6,195	27,739	326,157
High	142,526	225,212	28,371	64,240	23,062	79,774	7,208	69,978	NA	28,415	668,786
Total	370,997	429,241	45,374	146,882	37,294	115,775	18,093	121,533	6,195	100,432	1,391,816

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, S/F = spruce/fir, TL = timberline.

Table 7c—Acres by ownership, forest type, density, structure for Montana, west of the Continental Divide

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Acres										
Federal:											
Structure—											
No structure	5,808	17,466	NA	NA	NA	12,573	NA	6,381	NA	NA	42,228
Scattered	31,073	175,659	90,487	68,806	6,275	36,967	12,847	170,600	24,393	NA	617,107
One story	18,362	165,820	174,641	750,190	NA	74,386	49,257	158,011	23,305	NA	1,413,972
Two story	89,707	436,210	77,499	587,670	36,479	179,275	123,555	359,458	77,643	6,277	1,973,773
Multistoried	93,701	1,333,566	12,573	80,293	49,455	432,282	225,122	1,362,164	86,295	NA	3,675,451
Total	238,651	2,128,721	355,200	1,486,959	92,209	735,483	410,781	2,056,614	211,636	6,277	7,722,531
Density—											
Low	95,437	814,416	140,286	462,339	12,656	278,949	123,238	736,569	125,168	6,277	2,795,335
Moderate	99,844	779,985	118,485	556,166	60,580	321,761	166,692	709,248	55,477	NA	2,868,238
High	43,370	534,320	96,429	468,454	18,973	134,773	120,851	610,797	30,991	NA	2,058,958
Total	238,651	2,128,721	355,200	1,486,959	92,209	735,483	410,781	2,056,614	211,636	6,277	7,722,531
Private:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	60,693	91,628	26,364	43,628	12,895	18,038	11,863	21,191	NA	NA	286,300
One story	17,402	123,081	76,341	141,897	12,512	27,896	5,503	8,760	NA	NA	413,392
Two story	89,698	282,661	30,358	115,435	11,912	70,889	13,401	41,759	NA	13,941	670,054
Multistoried	105,136	641,207	NA	NA	26,865	206,791	25,295	47,788	4,160	36,232	1,093,474
Total	272,929	1,138,577	133,063	300,960	64,184	323,614	56,062	119,498	4,160	50,173	2,463,220
Density—											
Low	94,023	388,367	41,826	100,511	40,254	108,160	17,533	41,956	NA	13,941	846,571
Moderate	84,118	328,619	39,895	53,110	6,783	88,735	5,362	19,654	NA	11,216	637,492
High	94,788	421,591	51,342	40,254	17,147	126,719	33,167	57,888	4,160	25,016	872,072
Total	272,929	1,138,577	133,063	193,875	64,184	323,614	56,062	119,498	4,160	50,173	2,356,135
Other:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	4,752	14,661	7,760	12,900	NA	6,037	NA	6,037	NA	NA	52,147
One story	14,225	4,940	17,865	33,905	8,837	12,283	1,723	1,723	NA	NA	95,501

Table 7c—Acres by ownership, forest type, density, structure for Montana, west of the Continental Divide (continued)

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Acres										
Two story	42,898	46,875	13,231	40,207	9,504	21,288	3,446	11,299	NA	6,433	195,181
Multistoried	58,366	269,277	6,518	6,452	18,953	70,451	7,208	53,213	NA	NA	490,438
Total	120,241	335,753	45,374	93,464	37,294	110,059	12,377	72,272	NA	6,433	833,267
Density—											
Low	35,834	77,065	9,483	20,513	6,798	27,070	5,169	9,483	NA	NA	191,415
Moderate	26,977	78,622	7,520	26,286	7,434	8,931	0	11,392	NA	6,433	173,595
High	57,430	180,066	28,371	46,665	23,062	74,058	7,208	51,397	NA	NA	468,257
Total	120,241	335,753	45,374	93,464	37,294	110,059	12,377	72,272	NA	6,433	833,267

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, S/F = spruce/fir, TL = timberline.

Table 7d—Acres by ownership, forest type, density, structure for Montana, east of the Continental Divide

Forest structure and density[a]	Forest type										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Acres										
Federal:											
Structure—											
No structure	4,320	NA	NA	NA	NA	NA	NA	NA	11,691	11,333	27,344
Scattered	180,863	93,522	NA	98,361	9,662	24,678	NA	115,480	47,458	40,370	610,394
One story	35,537	169,888	NA	1,225,155	NA	NA	33,564	80,239	38,735	22,079	1,605,197
Two story	228,502	449,730	NA	680,550	12,286	37,017	48,963	298,378	93,401	77,461	1,926,288
Multistoried	259,759	1,064,069	NA	123,008	12,870	115,759	100,302	943,633	174,981	119,981	2,914,362
Total	708,981	1,777,209	NA	2,127,074	34,818	177,454	182,829	1,437,730	366,266	271,224	7,083,585
Density—											
Low	300,309	568,731	NA	632,730	9,662	109,629	64,151	446,331	162,353	107,156	2,401,052
Moderate	177,270	503,424	NA	721,618	6,049	42,516	63,483	520,616	52,166	81,389	2,168,531
High	231,402	705,054	NA	772,726	19,107	25,309	55,195	470,783	151,747	82,679	2,514,002
Total	708,981	1,777,209	NA	2,127,074	34,818	177,454	182,829	1,437,730	366,266	271,224	7,083,585
Private:											
Structure—											
No structure	17,340	NA	NA	NA	NA	NA	NA	NA	NA	NA	17,340
Scattered	175,284	65,267	NA	35,950	NA	NA	5,163	5,163	NA	18,172	304,999
One story	166,740	45,990	NA	128,017	14,324	11,309	5,499	17,319	NA	61,539	450,737
Two story	562,461	160,259	NA	77,279	16,305	11,370	9,385	19,796	NA	149,475	1,006,330
Multistoried	327,802	431,368	NA	40,940	6,554	NA	5,624	90,206	NA	117,174	1,019,668
Total	1,249,627	702,884	NA	282,186	37,183	22,679	25,671	132,484	NA	346,360	2,799,074
Density—											
Low	499,297	268,762	NA	174,907	5,499	22,679	10,662	44,208	NA	87,691	1,113,705
Moderate	397,958	221,231	NA	44,100	25,130	NA	0	30,664	NA	147,465	866,548
High	352,372	212,891	NA	63,179	6,554	NA	15,009	57,612	NA	111,204	818,821
Total	1,249,627	702,884	NA	282,186	37,183	22,679	25,671	132,484	NA	346,360	2,799,074
Other:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	34,698	13,941	NA	NA	NA	NA	NA	NA	NA	11,957	60,596
One story	11,718	14,674	NA	41,507	NA	NA	NA	13,344	NA	27,768	109,011

Table 7d—Acres by ownership, forest type, density, structure for Montana, east of the Continental Divide (continued)

Forest structure and density[a]	Forest type										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
						Acres					
Two story	107,526	13,532	NA	11,911	NA	NA	NA	18,769	NA	22,226	173,964
Multistoried	96,814	51,341	NA	NA	NA	5,716	5,716	17,148	6,195	32,048	214,978
Total	250,756	93,488	NA	53,418	NA	5,716	5,716	49,261	6,195	93,999	558,549
Density—											
Low	90,017	34,810	NA	24,442	NA	NA	NA	11,911	NA	44,278	205,458
Moderate	75,643	13,532	NA	11,401	NA	NA	5,716	18,769	6,195	21,306	152,562
High	85,096	45,146	NA	17,575	NA	5,716	NA	18,581	NA	28,415	200,529
Total	250,756	93,488	NA	53,418	NA	5,716	5,716	49,261	6,195	93,999	558,549

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, S/F = spruce/fir, TL = timberline.

Table 8—Acres by region, ownership, density, and structure

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Acres		
Montana:				
Structure—				
No structure	69,572	17,340	NA	86,912
Scattered	1,227,501	591,299	112,743	1,931,543
One story	3,019,169	864,129	204,512	4,087,810
Two story	3,893,784	1,676,384	369,145	5,939,313
Multistoried	6,596,090	2,113,142	705,416	9,414,648
All	14,806,116	5,262,294	1,391,816	21,460,226
Density—				
Low	5,196,387	1,960,276	396,873	7,553,536
Moderate	5,036,769	1,504,040	326,157	6,866,966
High	4,572,960	1,797,978	668,786	7,039,724
All	14,806,116	5,262,294	1,391,816	21,460,226
Structure/density—				
Scattered, low	1,227,501	591,299	112,743	1,931,543
Scattered, moderate	NA	NA	NA	NA
Scattered, high	NA	NA	NA	NA
One story, low	1,367,701	483,087	104,217	1,955,005
One story, moderate	913,055	227,531	29,126	1,169,712
One story, high	738,413	153,511	71,169	963,093
Two story, low	1,600,834	621,928	119,442	2,342,204
Two story, moderate	1,315,027	624,174	139,864	2,079,065
Two story, high	977,923	430,282	109,839	1,518,044
Multistoried, low	930,779	246,622	60,471	1,237,872
Multistoried, moderate	2,808,687	652,335	157,167	3,618,189
Multistoried, high	2,856,624	1,214,185	487,778	4,558,587
All	14,736,544	5,244,954	1,391,816	21,373,314
West of the Continental Divide:				
Structure—				
No structure	42,228	NA	NA	42,228
Scattered	617,107	286,300	52,147	955,554
One story	1,413,972	413,392	95,501	1,922,865
Two story	1,967,496	670,054	195,181	2,832,731
Multistoried	3,681,728	1,093,474	490,438	5,265,640
All	7,722,531	2,463,220	833,267	11,019,018
Density—				
Low	2,795,335	846,571	191,415	3,833,321
Moderate	2,868,238	637,492	173,595	3,679,325
High	2,058,958	979,157	468,257	3,506,372
All	7,722,531	2,463,220	833,267	11,019,018
Structure/density—				
Scattered, low	617,107	286,300	52,147	955,554
Scattered, moderate	NA	NA	NA	NA

Table 8—Acres by region, ownership, density, and structure (continued)

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Acres		
Scattered, high	NA	NA	NA	NA
One story, low	715,889	214,949	37,190	968,028
One story, moderate	399,388	95,788	23,441	518,617
One story, high	298,695	102,655	34,870	436,220
Two story, low	872,836	221,511	65,236	1,159,583
Two story, moderate	704,505	204,921	56,830	966,256
Two story, high	390,155	243,622	73,115	706,892
Multistoried, low	547,275	123,811	36,842	707,928
Multistoried, moderate	1,764,345	336,783	93,324	2,194,452
Multistoried, high	1,370,108	632,880	360,272	2,363,260
All	7,680,303	2,463,220	833,267	10,976,790
East of the Continental Divide:				
Structure—				
No structure	27,344	17,340	NA	44,684
Scattered	610,394	304,999	60,596	975,989
One story	1,605,197	450,737	109,011	2,164,945
Two story	1,926,288	1,006,330	173,964	3,106,582
Multistoried	2,914,362	1,019,668	214,978	4,149,008
All	7,083,585	2,799,074	558,549	10,441,208
Density—				
Low	2,401,052	1,113,705	205,458	3,720,215
Moderate	2,168,531	866,548	152,562	3,187,641
High	2,514,002	818,821	200,529	3,533,352
All	7,083,585	2,799,074	558,549	10,441,208
Structure/density—				
Scattered, low	610,394	304,999	60,596	975,989
Scattered, moderate	NA	NA	NA	NA
Scattered, high	NA	NA	NA	NA
One story, low	651,812	268,138	67,027	986,977
One story, moderate	513,667	131,743	5,685	651,095
One story, high	439,718	50,856	36,299	526,873
Two story, low	727,998	400,417	54,206	1,182,621
Two story, moderate	610,522	419,253	83,034	1,112,809
Two story, high	587,768	186,660	36,724	811,152
Multistoried, low	383,504	122,811	23,629	529,944
Multistoried, moderate	1,044,342	315,552	63,843	1,423,737
Multistoried, high	1,486,516	581,305	127,506	2,195,327
All	7,056,241	2,781,734	558,549	10,396,524

NA = no plots available.

Table 9—Basal area ranges for low, moderate, and high density classes, by forest type, and geographic region within Montana

Forest type[a] and density	Basal area		
	Low	Moderate	High
		Ft²/acre	
West of the Continental Divide:			
PP	<50	50–100	>100
DF	<90	90–150	>150
DLMC	<80	80–130	>130
WL	<50	50–125	>125
LP	<100	100–160	>160
MLMC	<130	130–210	>210
UMC	<110	110–160	>160
S/F	<85	85–145	>145
TL	<50	50–80	>80
East of the Continental Divide:			
PP	<40	40–75	>75
DF	<80	80–130	>130
DLMC	<60	60–130	>130
WL	NA	NA	NA
LP	<110	110–160	>160
MLMC	<130	130–210	>210
UMC	<100	100–160	>160
S/F	<100	100–160	>160
TL	<60	60–140	>140

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, SF = spruce/fir, TL = timberline.

Table 10—Average crowning index by region, ownership, density, and structure

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Montana:				
Structure—				
No structure	51	63	—	53
Scattered	69	66	71	68
One story	32	40	38	34
Two story	30	37	34	32
Multistoried	25	25	24	25
All	30	35	31	31
Density—				
Low	45	52	54	47
Moderate	27	34	29	29
High	20	21	22	21
All	30	35	31	31
Structure/density—				
Scattered, low	69	66	71	68
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	42	48	54	45
One story, moderate	27	37	25	29
One story, high	20	19	28	20
Two story, low	36	48	48	40
Two story, moderate	28	36	30	31
Two story, high	21	24	24	22
Multistoried, low	33	33	41	33
Multistoried, moderate	27	32	29	28
Multistoried, high	20	20	21	20
All	30	35	31	31
West of the Continental Divide:				
Structure—				
No structure	67	—	—	67
Scattered	75	61	75	71
One story	38	39	39	38
Two story	33	34	31	33
Multistoried	28	24	24	26
All	34	33	29	31
Density—				
Low	49	51	54	50
Moderate	29	33	28	30
High	23	20	22	22
All	34	33	29	31
Structure/density—				
Scattered, low	75	61	75	71
Scattered, moderate	—	—	—	—

Table 10—Average crowning index by region, ownership, density, and structure (continued)

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Scattered, high	—	—	—	—
One story, low	48	46	64	49
One story, moderate	31	41	25	32
One story, high	22	21	29	23
Two story, low	39	51	43	41
Two story, moderate	30	32	28	30
Two story, high	25	21	22	23
Multistoried, low	36	34	41	36
Multistoried, moderate	29	31	29	29
Multistoried, high	23	19	21	22
All	34	33	29	31
East of the Continental Divide:				
Structure—				
No structure	29	63	—	41
Scattered	63	70	65	65
One story	27	41	36	31
Two story	26	39	41	31
Multistoried	21	26	27	23
All	26	37	37	29
Density—				
Low	41	52	53	45
Moderate	25	36	32	28
High	18	22	24	19
All	26	37	37	29
Structure/density—				
Scattered, low	63	70	65	65
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	37	49	44	41
One story, moderate	24	35	23	26
One story, high	18	15	25	18
Two story, low	33	46	58	38
Two story, moderate	26	38	34	31
Two story, high	19	28	31	21
Multistoried, low	27	33	40	29
Multistoried, moderate	24	32	31	27
Multistoried, high	18	21	22	19
All	26	37	37	29

— = insignificant data available.

Table 11a—Average crowning index by region, forest type, density, and structure

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Mph										
Montana:											
Structure—											
No structure	62	63	NA	NA	NA	79	NA	42	25	24	53
Scattered	61	74	107	66	61	61	62	63	63	64	68
One story	57	51	48	25	33	45	31	34	27	45	34
Two story	40	34	37	24	33	38	31	27	24	41	32
Multistoried	30	25	32	27	29	25	27	22	17	25	25
Total	42	33	57	28	34	32	30	27	25	37	31
Density—											
Low	58	50	94	40	50	45	39	39	36	50	47
Moderate	38	28	47	25	34	28	30	24	18	39	29
High	27	20	32	19	23	21	22	19	14	20	21
Total	42	33	57	28	34	32	30	27	25	37	31
West of the Continental Divide:											
Structure—											
No structure	76	63	NA	NA	NA	79	NA	42	NA	NA	67
Scattered	56	78	107	49	72	50	53	72	56	NA	71
One story	82	55	48	27	38	45	31	35	37	NA	38
Two story	43	37	37	24	38	39	33	29	28	33	33
Multistoried	35	26	32	27	31	25	30	24	19	33	26
Total	45	35	57	28	37	32	32	30	29	33	33
Density—											
Low	62	53	94	39	51	46	41	43	36	43	50
Moderate	46	29	47	24	38	29	32	26	22	33	30
High	29	21	32	20	25	22	24	20	14	26	22
Total	45	35	57	28	37	32	32	30	29	33	33
East of the Continental Divide:											
Structure—											
No structure	58	NA	NA	NA	NA	NA	NA	NA	25	24	41
Scattered	62	67	NA	85	44	89	101	48	67	64	65
One story	50	47	NA	24	16	49	31	32	21	45	31

Table 11a—Average crowning index by region, forest type, density, and structure (continued)

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
						Mph					
Two story	40	31	NA	24	24	34	23	24	20	42	31
Multistoried	28	23	NA	27	27	22	22	19	16	24	23
Total	41	30	NA	27	25	35	26	23	24	37	29
Density—											
Low	57	45	NA	40	44	44	35	32	36	51	45
Moderate	36	27	NA	25	19	18	26	22	15	40	28
High	26	19	NA	18	17	19	17	17	14	20	19
Total	41	30	NA	27	25	35	26	23	24	37	29

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, SF = spruce/fir, TL = timberline.

Table 11b—Average crowning index by ownership, forest type, density, and structure for Montana

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
						Mph					
Federal:											
Structure—											
No structure	60	64	NA	NA	NA	79	NA	42	25	24	51
Scattered	58	68	122	67	68	68	52	65	63	73	69
One story	68	54	52	25	NA	55	30	34	27	39	32
Two story	40	33	44	24	35	37	32	27	24	25	29
Multistoried	31	26	30	29	31	27	27	23	17	15	25
Total	43	33	67	27	38	35	29	27	26	29	30
Density—											
Low	56	49	106	38	59	45	36	39	36	47	45
Moderate	40	29	45	25	39	29	30	24	18	21	27
High	27	20	37	19	21	24	22	19	15	12	20
Total	43	33	67	27	38	35	29	27	26	29	30
Private:											
Structure—											
No structure	63	NA	NA	NA	NA	NA	NA	NA	NA	NA	63
Scattered	63	77	73	63	50	47	69	52	NA	61	66
One story	51	42	48	29	34	35	29	32	NA	52	40
Two story	39	36	29	27	32	45	21	29	NA	50	37
Multistoried	28	24	NA	22	27	24	23	21	9	32	25
Total	41	33	49	32	33	32	34	27	9	43	35
Density—											
Low	57	50	63	44	45	46	55	43	NA	61	52
Moderate	38	29	63	30	22	25	28	25	NA	49	34
High	25	19	26	18	23	20	20	17	9	25	21
Total	41	33	49	32	33	32	34	27	9	43	35
Other:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	63	104	72	72	0	30	NA	23	NA	38	70
One story	72	69	32	26	32	33	50	34	NA	36	38

Table 11b—Average crowning index by ownership, forest type, density, and structure for Montana (continued)

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
						Mph					
Two story	46	32	25	20	29	34	25	23	NA	43	34
Multistoried	32	24	33	16	27	20	32	18	14	27	24
Total	43	30	35	28	28	24	32	20	14	35	31
Density—											
Low	68	54	70	50	44	43	46	30	NA	41	54
Moderate	38	27	29	18	29	25	32	24	14	41	29
High	30	21	27	19	26	20	22	17	NA	20	22
Total	43	30	35	28	28	24	32	20	14	35	31

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, SF = spruce/fir, TL = timberline.

Table 11c—Average crowning index by ownership, forest type, density, and structure for Montana, west of the Continental Divide

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Mph										
Federal:											
Structure—											
No structure	76	64	NA	NA	NA	79	NA	42	NA	NA	67
Scattered	56	73	122	45	116	54	52	75	56	NA	75
One story	107	60	52	27	NA	55	30	35	37	NA	38
Two story	45	39	44	25	41	37	35	30	28	NA	33
Multistoried	44	29	30	30	34	28	30	25	20	41	28
Total	52	37	67	27	42	35	32	31	29	41	34
Density—											
Low	61	53	106	37	75	46	39	43	36	41	49
Moderate	50	30	45	25	41	30	32	26	22	NA	29
High	36	23	37	21	25	25	25	21	15	NA	23
Total	52	37	67	27	42	35	32	31	29	41	34
Private:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	60	78	73	38	50	47	53	54	NA	NA	61
One story	59	45	48	29	43	28	17	50	NA	NA	39
Two story	38	36	29	24	37	48	24	25	NA	35	34
Multistoried	30	23	NA	NA	30	24	25	23	9	32	24
Total	41	33	49	28	38	31	30	31	9	33	33
Density—											
Low	57	53	63	40	45	48	45	47	NA	44	51
Moderate	44	29	63	30	31	25	28	23	NA	35	33
High	24	18	26	19	25	20	21	21	9	26	20
Total	41	33	49	28	38	31	30	31	9	33	33
Other:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	27	117	72	72	NA	30	NA	23	NA	NA	75

Table 11c—Average crowning index by ownership, forest type, density, and structure for Montana, west of the Continental Divide (continued)

Forest structure and density	Forest type [a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
						Mph					
One story	79	79	32	27	32	33	50	29	NA	NA	39
Two story	48	32	25	18	29	34	25	24	NA	28	31
Multistoried	33	24	33	16	27	20	32	17	NA	NA	24
Total	43	29	35	29	28	24	32	19	NA	28	29
Density—											
Low	74	53	70	57	44	43	46	25	NA	NA	54
Moderate	41	27	29	17	29	25	NA	28	NA	28	28
High	32	20	27	19	26	20	22	17	NA	NA	22
Total	43	29	35	29	28	24	32	19	NA	28	29

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, SF = spruce/fir, TL = timberline.

Table 11d—Average crowning index by ownership, forest type, density, and structure for Montana, east of the Continental Divide

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
	Mph										
Federal:											
Structure—											
No structure	44	NA	NA	NA	NA	NA	NA	NA	25	24	29
Scattered	58	60	NA	82	44	89	NA	48	67	73	63
One story	48	49	NA	24	NA	NA	29	32	21	39	27
Two story	38	28	NA	23	17	36	24	23	20	25	26
Multistoried	27	23	NA	28	18	22	22	19	16	13	21
Total	40	28	NA	26	26	35	23	23	24	29	26
Density—											
Low	54	43	NA	39	44	45	28	31	36	47	41
Moderate	34	27	NA	25	22	18	25	22	15	21	25
High	25	18	NA	18	16	18	17	17	14	12	18
Total	40	28	NA	26	26	35	23	23	24	29	26
Private:											
Structure—											
No structure	63	NA	NA	NA	NA	NA	NA	NA	NA	NA	63
Scattered	64	76	NA	98	NA	NA	101	48	NA	61	70
One story	50	36	NA	28	16	49	41	23	NA	52	41
Two story	39	37	NA	31	28	29	17	38	NA	51	39
Multistoried	27	25	NA	22	17	0	16	20	NA	32	26
Total	41	33	NA	36	23	39	43	24	NA	44	37
Density—											
Low	57	46	NA	47	45	39	71	39	NA	64	52
Moderate	36	29	NA	29	18	NA	NA	27	NA	50	36
High	25	20	NA	15	17	NA	16	14	NA	25	22
Total	41	33	NA	36	23	39	43	24	NA	44	37
Other:											
Structure—											
No structure	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Scattered	69	78	NA	NA	NA	NA	NA	NA	NA	38	64

Table 11d—Average crowning index by ownership, forest type, density, and structure for Montana, east of the Continental Divide (continued)

Forest structure and density	Forest type[a]										
	PP	DF	WL	LP	DLMC	MLMC	UMC	S/F	TL	Other	Total
						Mph					
One story	57	59	NA	24	NA	NA	NA	37	NA	36	36
Two story	44	32	NA	33	NA	NA	NA	22	NA	47	41
Multistoried	31	23	NA	NA	NA	21	32	20	NA	27	27
Total	43	37	NA	26	NA	21	32	25	NA	36	37
Density—											
Low	65	60	NA	33	NA	NA	NA	37	NA	NA	53
Moderate	35	24	NA	22	NA	NA	32	20	NA	44	32
High	27	25	NA	19	NA	21	NA	22	NA	20	24
Total	43	37	NA	26	NA	21	32	25	NA	36	37

NA = no plots recorded.

[a] Forest type abbreviations definitions are PP = ponderosa pine, DF = Douglas-fir, WL = western larch, LP = lodgepole pine, DLMC = dry lower mixed conifer, MLMC = moist lower mixed conifer, UMC = upper mixed conifer, SF = spruce/fir, TL = timberline.

Table 12—Average pre- and posttreatment crowning indexes by region, ownership, density, and structure: thin from below to 9 in treatment

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Montana:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	33/38	34/41	29/40	33/40
Two story	31/37	32/43	37/49	32/40
Multistoried	26/31	23/35	25/42	25/32
All	27/33	26/37	27/33	27/34
Density—				
Low	34/39	33/39	39/39	34/39
Moderate	30/35	31/43	32/42	30/38
High	22/28	21/33	23/30	22/30
All	27/33	26/37	27/33	27/34
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	33/42	36/38	—	35/40
One story, moderate	31/32	34/43	33/38	33/40
One story, high	—	—	21/45	21/45
Two story, low	38/39	33/37	38/38	36/38
Two story, moderate	31/38	33/46	37/55	33/44
Two story, high	24/32	29/39	36/44	27/36
Multistoried, low	32/39	31/41	40/40	33/40
Multistoried, moderate	29/34	29/41	29/33	29/35
Multistoried, high	22/28	20/32	23/29	21/29
All	27/33	26/37	27/33	27/34
West of the Continental Divide:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	31/31	34/34	29/40	32/35
Two story	35/38	30/35	36/44	33/38
Multistoried	28/30	22/25	25/27	26/28
All	29/32	24/28	26/30	27/30
Density—				
Low	37/37	33/33	39/39	36/36
Moderate	31/34	30/34	31/36	31/35
High	24/26	20/24	23/26	22/25
All	29/32	24/28	26/30	27/30

Table 12—Average pre- and posttreatment crowning indexes by region, ownership, density, and structure: thin from below to 9 in treatment (continued)

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	—	40/40	-/-	40/40
One story, moderate	31/31	25/25	33/38	29/31
One story, high	—	—	21/45	21/45
Two story, low	38/38	32/32	38/38	36/36
Two story, moderate	35/39	34/43	36/50	35/42
Two story, high	28/32	26/32	27/44	27/32
Multistoried, low	35/35	31/32	40/40	36/36
Multistoried, moderate	30/33	29/32	29/32	30/33
Multistoried, high	24/25	19/22	23/25	22/24
All	29/32	24/28	26/30	27/30
East of the Continental Divide:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	33/41	35/45	—	34/43
Two story	27/36	33/47	38/55	31/43
Multistoried	23/33	24/45	23/49	23/37
All	24/34	28/46	29/51	26/39
Density—				
Low	31/42	32/47	—	31/44
Moderate	27/36	32/48	36/58	30/42
High	21/30	23/44	26/48	22/36
All	24/34	28/46	29/51	26/39
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	33/42	30/37	—	32/40
One story, moderate	33/35	36/47	—	36/46
One story, high	—	—	—	—
Two story, low	36/42	36/48	—	36/44
Two story, moderate	28/38	33/48	37/59	31/45
Two story, high	22/32	33/47	39/44	27/38
Multistoried, low	28/43	30/51	—	29/45
Multistoried, moderate	27/36	30/48	26/50	28/40
Multistoried, high	20/30	21/43	23/49	21/35
All	24/34	28/46	29/51	26/39

— = insignificant data available.

Table 13—Average pre- and posttreatment crowning indexes by region, ownership, density, and structure: 50-percent BA removal treatment

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Montana:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	31/76	31/38	23/45	30/46
Two story	27/45	29/43	32/57	28/45
Multistoried	25/53	22/46	24/56	24/51
All	25/51	24/45	25/56	25/50
Density—				
Low	32/38	28/33	34/47	31/38
Moderate	29/53	29/45	30/53	29/51
High	21/51	21/46	23/58	22/51
All	25/51	24/45	25/56	25/50
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	—	30/32	—	30/32
One story, moderate	31/76	33/41	25/42	32/49
One story, high	—	19/21	21/48	20/35
Two story, low	38/46	27/31	30/56	33/42
Two story, moderate	29/45	31/42	32/51	30/45
Two story, high	21/45	27/45	36/75	24/47
Multistoried, low	29/34	29/35	37/43	30/35
Multistoried, moderate	28/55	28/47	29/54	28/53
Multistoried, high	21/52	20/46	22/57	21/51
All	25/51	24/45	25/56	25/50
West of the Continental Divide:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	31/73	25/35	23/45	26/51
Two story	31/52	25/40	30/55	29/48
Multistoried	27/58	21/47	24/57	25/55
All	28/57	22/45	24/56	26/54
Density—				
Low	35/44	30/36	34/47	34/43
Moderate	30/57	27/42	29/54	30/53
High	24/60	19/47	22/58	22/55
All	28/57	22/45	24/56	26/54

Table 13—Average pre- and posttreatment crowning indexes by region, ownership, density, and structure: 50% BA removal treatment (continued)

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	—	—	—	—
One story, moderate	31/73	25/35	25/42	27/51
One story, high	—	—	21/48	21/48
Two story, low	37/49	29/36	30/56	33/46
Two story, moderate	33/51	28/40	31/53	31/48
Two story, high	25/56	22/42	27/61	24/49
Multistoried, low	33/41	32/37	37/43	34/41
Multistoried, moderate	29/58	27/44	29/54	29/55
Multistoried, high	24/60	19/48	22/58	22/56
All	28/57	22/45	24/56	26/54
East of the Continental Divide:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	33/82	33/39	—	33/44
Two story	23/40	31/44	35/59	27/43
Multistoried	22/47	23/45	24/53	22/47
All	22/46	26/44	28/55	24/46
Density—				
Low	29/32	26/30	—	28/32
Moderate	26/47	31/46	32/49	28/47
High	19/46	23/44	26/58	21/46
All	22/46	26/44	28/55	24/46
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	—	30/32	—	30/32
One story, moderate	33/82	35/43	—	35/48
One story, high	—	19/21	—	19/21
Two story, low	39/43	23/24	—	34/37
Two story, moderate	26/40	32/43	33/49	29/42
Two story, high	19/40	31/48	39/79	24/46
Multistoried, low	25/28	26/33	—	25/29
Multistoried, moderate	26/50	28/50	26/48	27/50
Multistoried, high	19/47	21/44	24/54	20/47
All	22/46	26/44	28/55	24/46

— = insignificant data available.

Table 14—Average pre- and posttreatment crowning indexes by region, ownership, density, and structure: comprehensive treatment

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Montana:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	28/107	32/69	30/68	31/80
Two story	29/83	30/74	32/93	30/81
Multistoried	25/83	24/77	25/88	25/82
All	26/84	26/76	26/89	26/82
Density—				
Low	33/82	32/83	36/93	33/84
Moderate	29/82	30/72	30/75	30/78
High	22/86	21/77	23/94	22/84
All	26/84	26/76	26/89	26/82
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	25/107	33/92	—	29/99
One story, moderate	31/130	34/62	33/70	33/77
One story, high	28/38	19/30	27/67	25/50
Two story, low	36/86	33/82	34/104	35/88
Two story, moderate	30/83	31/71	32/80	31/77
Two story, high	22/81	27/76	39/103	25/81
Multistoried, low	31/77	31/81	29/79	32/78
Multistoried, moderate	29/81	29/76	29/71	29/79
Multistoried, high	21/87	20/78	22/94	21/85
All	26/84	26/76	26/89	26/82
West of the Continental Divide:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	27/137	31/94	29/73	29/103
Two story	33/88	27/90	30/104	31/92
Multistoried	28/88	23/85	25/90	26/88
All	29/88	24/87	26/92	27/89
Density—				
Low	35/89	33/95	36/93	35/91
Moderate	30/89	28/87	29/78	30/87
High	24/88	20/85	22/97	22/90
All	29/88	24/87	26/92	27/89

Table 14—Average pre- and posttreatment crowning indexes by region, ownership, density, and structure: comprehensive treatment (continued)

Forest structure and density	Ownership			
	Federal	Private	Other	Total
		Mph		
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	23/148	34/113	—	30/127
One story, moderate	31/125	25/67	33/70	29/87
One story, high	—	—	21/80	21/80
Two story, low	37/87	32/89	34/104	35/91
Two story, moderate	33/93	28/92	28/96	31/93
Two story, high	25/80	23/88	26/114	24/89
Multistoried, low	33/86	34/94	39/79	35/86
Multistoried, moderate	30/87	29/85	29/72	29/85
Multistoried, high	24/89	19/85	22/96	22/90
All	29/88	24/87	26/92	27/89
East of the Continental Divide:				
Structure—				
No structure	—	—	—	—
Scattered	—	—	—	—
One story	29/77	33/58	32/53	32/63
Two story	26/80	32/64	35/74	29/72
Multistoried	23/79	24/70	24/77	23/75
All	24/79	27/67	29/75	25/74
Density—				
Low	30/73	31/69	—	30/71
Moderate	27/74	32/64	33/67	30/69
High	20/84	23/70	27/81	21/79
All	24/79	27/67	29/75	25/74
Structure/density—				
Scattered, low	—	—	—	—
Scattered, moderate	—	—	—	—
Scattered, high	—	—	—	—
One story, low	27/66	30/60	—	29/63
One story, moderate	33/139	36/61	—	36/70
One story, high	28/38	19/30	32/53	26/40
Two story, low	34/85	34/74	—	34/81
Two story, moderate	28/76	32/62	35/68	31/68
Two story, high	20/82	30/66	36/89	25/76
Multistoried, low	28/66	28/67	—	28/66
Multistoried, moderate	27/71	30/68	28/62	28/69
Multistoried, high	20/85	21/71	24/80	20/80
All	24/79	27/67	29/75	25/74

— = insignificant data available.

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